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ABSTRACTS OF FIVE BIOMEDICAL PAPERS ON RESULTS OF SOVIET MANNED SPACE FLIGHTS

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RESULTS OF SOME ELECTROPHYSIOLOGICAL INVESTIGATIONS CONDUCTED ON THE VOSKHOD-1 SPACECRAFT

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ABSTRACT

Previous spaceflights by Soviet and American cosmonauts permitted studies of functional changes occurring in a number of systems in the human organism. However, such problems as working ability, the degree of movement coordination, and the maintainance of the motor stereotype established on Earth have remained unclear. In view of the complexity of these problems, it was most expedient to include a cosmonaut-physician with appropriate instruments in the crew in an attempt to elucidate them. This idea was put into practice in the Voskhod-1 flight.

In this report we will focus on results of some electrophysiological investigations conducted during the flight by special methods with the help of a "Polinom" apparatus.

This apparatus permitted the recording of four physiological parameters for each cosmonaut: electroencephalogram (EEG), electrooculogram (EOG), dynamogram (DMG), and probes of movement coordination when writing (writing coordination-WC).

With the aim of most effectively making use of time, a special program was developed which consisted of the following:

1. At the beginning of the program, each member of the crew gave his marker signal (reference signal).

2. Following the marker, two tests were conducted in the course of 40 seconds on the opening and closing of the eyes with a simultaneous EEG registration.

3. A test was conducted on a special pickup on the accuracy of completing four double spirals, four numeral six's, and signature when writing with opened and closed eyes.

4. In the course of a minute, a wrist dynamograph with equal force and duration was compressed.

5. Three movements of the eyes to the left and three to the right at the same angle from the center of the glance were alternately conducted. After that ten turning movements of the head from left to right immediately followed by a repeated probe of eye coordination took place.

At the end of the program, each cosmonaut repeated his marker signal.

An investigation of EEG's obtained during the flight permitted an evaluation of the dynamics of excitatory and inhibitory processes in the brain cortex. Analysis of the writing test conducted during the flight facilitated an evaluation of the accuracy of performing motor exercises developed in the process of preparation and provided for identifying symptoms of fatigue.

An investigation of EOG's facilitated the evaluation of oculomotor activity and the excitability of the vestibular apparatus.

Observed physiological shifts were functional in nature and reflected processes of adaptation of the human organism to spaceflight conditions.

The results of the conducted investigations indicate the effectiveness of the methods and apparatus used and provide the basis for recommending their use on future spaceflights.

PROBLEMS OF EVALUATING COSMONAUT WORK CAPACITY (BASED ON DATA FROM THE FLIGHTS OF "VOSKHOD-1" AND "VOSKHOD-2")

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ABSTRACT

1. The progress made by Soviet science and technology in the preparation and execution of space flights has increased their reliability to such a degree that the problems of life support for short-term orbital flights, which at the time of the first flights were basic to the general problem of the conquest of space, are beginning to give way to new investigations concerned with study of the work capacity of crew members and their reliability as links in the control system.

2. Such investigations were begun with members of the crew of the "Voskhod-1" spacecraft. On this flight, the most general functions of the human pilot, which at the same time are the functions most essential to human activity, were studied by the complex method. The data thus obtained have been helpful in setting up programs for longer, more complicated flights.

3. The following methods were used to accomplish these ends:

- the study analysis of work operations;
- investigation of visual operational work capacity;
- investigation of the characteristics of analysis, quality of operational memory, and perception during exercises with regular and random line circuits;
- study of the resolving power of the visual apparatus.

4. Studies using the above methods were conducted under laboratory conditions, on a spacecraft training mockup, and in a climate chamber simulating the spacecraft cabin. The results obtained were compared with flight results.

5. The flight program for "Voskhod-2" consisted of a great variety of activities, not only involving complex decision making but also complex procedures in execution. A sequence of coordinated and closely interrelated kinds of activity was worked up under terrestrial conditions and repeated under conditions of spaceflight during the extravehicular excursion. No striking differences in either performance or tempo were observed.

6. The operational habits trained into the spacecraft commander on Earth did not desert him. During the culminating phase of the flight, while the copilot was outside the vessel, he accurately and correctly oriented the ship, supervised the EVA, and monitored the condition of the man outside.

7. During the flight of "Voskhod-2", in addition to the first extravehicular venture into space and airlock exercises into total vacuum, the cosmonauts worked for the first time with modeling equipment. It was possible to obtain the square error of piloting operations, correlational data on human input and output parameters, and also to study the characteristics of the control process and data transmission functions of the human link in the control system. In addition, the latent period of human motor reactions to signals of different forms were studied for the first time under spaceflight conditions. The above-mentioned characteristics were obtained for conditions of both direct and delayed feedback.

8. The studies which were carried out made it possible to arrive at the following conclusions:

- the pilot's control activity changes somewhat during the first stages of flight, all evidence indicating that this change is dependent not

only on the transition from acceleration to weightlessness and the commencement of the adaptation phase, but also on the emotional content of the first hours of the flight;

- visual resolution undergoes no significant change in persons with normal visual acuity, which was the basis for observation of an artificial Earth satellite and determination of the distance to it; studies of operational visual work capacity showed that some change does occur;
- the greatest difference was noted in analysis of the quality of operational memory, which changed in all members of the crew;
- in designing spacecraft control systems it is essential to make allowance for the fact that the parameters of human motor output under conditions of weightless differ somewhat from control conditions in the direction of greater amplitude of rational control impulses;
- in the course of tracking activity, delay occurs, causing increased error values paralleling increased input parameter frequency;
- activity prediction elements under spaceflight conditions differ slightly from the same values obtained under Earth conditions.

SOME RESULTS OF PHYSIOLOGICAL AND ECOLOGICAL INVESTIGATIONS OF CHLORELLA CULTURES AS A LINK IN AN ECOSYSTEM

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ABSTRACT

1. It is acknowledged that the potential possibilities of algal cultures can only be realized by combining high suspension density with the maintainance of optimum cultivation conditions in all parts of the suspension. Perfection of this combination of factors makes it possible to increase the productivity of Chlorella suspensions up to 8-10 liters of oxygen per liter of suspension per hour.

2. Tests in cultivation vessels closed according to the gas phase revealed a quantitative correlation between the consumption of carbon dioxide and mineral elements on one hand and the production of biomass of a given composition and oxygen on the other. This makes it possible to compute the actual material balance of algal cultures as a function of one or a few factors.

3. The intensive cultivation of Chlorella in high density suspension is accompanied by the accumulation of gasseous mixtures in the regenerated atmosphere in concentrations which are intolerable to man. Also observed was the accumulation of biologically active substances in the culture medium. According to the degree of increase in concentration, the initial stimulating effect of these substances on growth becomes inhibitory.

4. Preliminary data obtained from the experiments on the permissible limitations of using Chlorella biomass in the rations of birds and humans indicates the necessity

for conducting further investigations aimed at extending these limitations.

5. At the very least, these complex investigations are necessary for quantitatively evaluating and calculating material relationships in an ecological niche of organisms includable in a biological system.

PHYSIOLOGICAL REACTIONS OF MAN TO ACCELERATIONS DURING SPACEFLIGHTS

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ABSTRACT

1. A study of the physiological reactions of cosmonauts to spaceflight accelerations and their comparison with data obtained from laboratory centrifugal studies is of great significance in the prognosis of working ability, general stability during the launch and reentry of the spacecraft, and establishing methods of preparing man for spaceflights.

2. Subjectively, all cosmonauts experienced approximately the same sensations during insert into orbit as they did during centrifugation. Accelerated pulse and respiration rates observed in the pre-launch period continued to increase during the beginning of the flight. Of great significance is the fact that these indices reached their peak in the first tens of seconds of the flight when the acceleration forces were not great. Then, inspite of the fact that G forces continued to increase, there occurred a steady decrease in the level of physiological shifts.

In the flights of the Vostok series, changes in autonomic functions were significantly more evident than in the Voskhod flights. This can evidently be attributed to a lower level of neuro-emotional stress manifested by the crews of group flights.

3. Autonomic reactions during spacecraft reentry through atmospheric layers were more intense as a rule than during the insert of the spacecraft into

orbit. The pulse rates of a number of cosmonauts reached peaks of 184-190 beats/minute. It is important to note that the magnitude of the reaction during this phase was greater than under the effects of analagous centrifugal G forces. The majority of cosmonauts suffered from visual disruptions in the form of "grey shrouds" during this phase of the flight which did not occur during accelerations under laboratory conditions. These data can most likely be explained from the standpoint of increased neuro-emotional stress during this period on one hand, and exposure to weightlessness beforehand which affected the functional level of mechanisms regulating circulation on the other.

4. To clarify the role of hypodynamia and altered hydrostatic pressure which occur in spaceflights and their effects on stability to G forces we conducted experiments on 21 healthy men aged 20-25 years.

The results of laboratory studies revealed that the maximum endurance time to transverse accelerations of 7 G after 20 days of hypodynamia decreased to 4-6 seconds compared to 4-5 minutes for control rotations.

At the most, the endurance value of acceleration following 8-15 days of hypokinesia was lowered on the average by 2 G. This decriment was directly dependent on individual resistance to acceleration and ranged from 0.7 to 4 G. In addition, it was established that exposure to equivalent magnitudes of acceleration was accompanied by far greater stress on physiological systems of the organism. Forinstance, at 8-9 G, the mean pulse rate was 170 ± 11 beats/minute after hypodynamia compared to 140 ± 13 beats/minute during control rotations. It was shown that the degree of altered resistance to accelerations depend to a large measure on the duration of hypokinesia.

Manifestations of faintness, visual disturbances, and lowered arterial pressure in vessels of the pinna (ear) during accelerations followed by a

subsequent increase in diastolic pressure leads to the proposition that altered vascular tonus plays a leading role in lowered resistance to accelerations after hypokinesia. The time taken for the restoration of all physiological indices was increased to 55-60 minutes compared to a control value of 5-15 minutes.

Hemorrhagic manifestations following accelerations which were preceded by bedrest were far more noticeable than under control conditions. In a few subjects at the end of the bedrest program, there were indications of a tendency towards fragility of small vessels and manifestations of a positive endothelial syndrome combined with changes in the size and form of capillaries.

The experiments indicated that even an unequivalent imitation of weightlessness leads to lowered resistance of man to accelerations.

With an increase in the duration of orbital flights, it is likely that the "de-training" influence of weightlessness on the cardiovascular, muscular, and other systems will become more intense. This can lead to a higher degree of lowered resistance to accelerations.

5. The execution of a system of complex exercises during bed rest combined with the use of pharmacological agents had positive results in a number of cases.

A consideration and evaluation of the prospect of acclimatization to hypoxia as a non-specific method of increasing resistance to accelerations is arrived at. In our experiments on animals and studies of human subjects, it was found that 15-30 day acclimatizations to pressure chamber conditions and high mountain altitudes increase the resistance of the organism to accelerations. The report will offer material illustrating these situations.

THE PROBLEM OF NOISE NORMALIZATION IN LIFE SUPPORT SYSTEMS IN SPACECRAFT CABINS DURING PROLONGED FLIGHT

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ABSTRACT

1. The constant presence in the spacecraft cabin of noise caused by the operation of the life support system may interfere with the comfort and even lead to deterioration of the work capacity of the cosmonaut.

2. In order to prevent the unpleasant effect of noise on the cosmonaut organism it is necessary to work out the physiologically permissible levels of acoustical stimulation. Such calculations as a rule will take into account the intensity of the noise, its spectral composition, and the duration of action. The permissible levels of noise in industry, where persons are exposed up to 7 hours out of 24, are essentially different from those under conditions of prolonged spaceflights.

3. On spacecraft without any special compartments for sleep or rest, the permissible noise characteristics should approximate the levels recommended for living quarters. According to the data of E. Konecci, the permissible noise levels under conditions of continuous and prolonged exposure of humans should not exceed 40 db. K. L. Karagodina considers the optimal noise level in living areas to be 35 db during the daytime, and 30 db at night.

4. In 92 experiments which we conducted with the participation of 63 subjects, data were obtained which indicate that humans show a good tolerance to high-frequency noise at an intensity of 60-65 db for exposures of up to 60 days.

The above-mentioned studies indicate that man has a high resistance to prolonged and continuous exposure to noise of medium volume.

On spacecraft having special compartments for work, sleep, and rest, the permissible noise levels must be differentiated according to the actual purpose of each of the compartments. In the sleeping and resting compartments, the maximum intensity and frequency values for noise must not exceed the permissible levels which we have set (60-65 db).

5. In the spacecraft control compartment, where the cosmonaut is obliged to monitor the operation of navigation instruments for several hours, maintain voice contact with the other crew members, and so forth, the noise level should not exceed the above-indicated parameters. In establishing noise levels for the working compartments, the nature of the activity and the length of time the cosmonaut must spend in them must be taken into account. During a 2-hour watch, the cosmonaut may be subjected to noise not exceeding 85 db in total level.

In auxiliary compartments, where the cosmonaut goes only at intervals for short periods, the noise level can be considerably higher. The setting of proper physiological hygienic norms for noise in the various compartments of the spacecraft assures satisfactory performance of the cosmonaut even under conditions of extremely prolonged flight.

6. The unique nature of spaceflight conditions requires not only that generally accepted concepts of rational physiological and hygienic norms be followed, but at the same time bring to the fore new problems and solutions in providing acoustical comfort in the cabin. It is extraordinary importance that under spaceflight conditions, the exposure to noise takes place continuously and against a background of altered emotional and volitional content. It must also be considered that by comparison with Earth, sound signals increase

considerably in "specific weight" and significance among the other stimuli which keep the cosmonaut informed as to the progress of the flight and the state of the external environment. For this reason, in addition to the conventional hygienic aspect of the noise background, the psychoacoustic effects of noise take on tremendous significance.

7. The basic acoustic noise in the cabin during the entire flight is that produced by the continuously operating fans of the life support system. Fan noise is characterized by considerable stability in both amplitude and spectral composition. From the psychoacoustic standpoint it constitutes a monotonous, unpleasant stimulus. A new and extremely essential problem under these conditions is that of the elimination of the unpleasant physiological and psychoacoustic effects of acoustical stimuli of medium and low intensity. In this connection, periodic alteration, controlled by the cosmonaut, of the frequency characteristic of the noise, while leaving the level of volume unchanged, has been found effective. According to our data, a constant noise with a volume of 58-60 db, may be considered permissible for spacecraft cabins. For conversion of physical noise characteristics into volume levels it is convenient to use the methods proposed by Stevens and Zwicker.

8. Complex measures for establishing not only permissible, but also minimum noise levels, together with the working out of ways of eliminating the unpleasant effects of prolonged continuous exposure to sound, must be regarded as a single problem in creating an optimal acoustical background for spacecraft cabins under conditions of prolonged spaceflights.